The Influence of Platform Switching on Clinical, Laboratory, and Image-Based Measures: A Prospective Clinical Study

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ABSTRACT

Purpose: This prospective study was conducted to compare the marginal bone level alterations, stability/mobility measurements, and volume of myeloperoxidase (MPO) and nitric oxide (NO) of peri-implant sulcus fluid (PISF) between platform-switched (PS) and standard platform (SP) implants inserted to mandibular premolar/molar regions with a single-stage protocol.

Materials and Methods: Thirty-two (16 PS and 16 SP) implants restorated with fixed prosthesis were included in the study. For both implant systems standard implant dimensions were used. Implant abutment connections and final restorations were made after 3 months of osseointegration. Standard parallel periapical radiographs were used to measure marginal bone loss in over time. Resonance frequency analysis (RFA) and mobility measuring (MM) device were used to determine implant stability/mobility. PISF samples were derived with paper strips and PISF MPO and nitrite level analysis were done spectrophotometrically. Peri-implant parameters were assessed by periodontal indices and all parameters were evaluated at baseline, 1, 3, 6, and 12 months follow-up.

Results: No healing problems were recorded for all implants at the end of the study period. At 12 months, mean bone loss measures were 0.84 and 0.76 mm, and mean implant stability quotient (ISQ) values were 74.04 and 76 for PS and SP implants, respectively. Mean MM values were found as −4.82 for PS and −6.26 for SP implants. There were no significant differences between implant types according to PISF volume and laboratory biochemical measures including MPO and NO, and clinical peri- implant indices at any time point.

Conclusion: Platform switching seems not to affect the marginal bone level, clinical peri-implant parameters and MPO and NO metabolism around implants inserted to mandibular premolar/molar regions when using a single-stage protocol.

KEY WORDS: dental implants, marginal bone loss, myeloperoxidase, nitric oxide, stability

INTRODUCTION

Platform switching (PS) is a current concept introduced to implant dentistry, where the applied abutment diameter is smaller than the implant collar diameter.[1,2] This type of connection changes the outside of the implant-abutment connection inward on the way to the central axis of the dental implant.[2] PS may increase the distance between the implant-abutment interface association inflammatory cell infiltrate and the marginal bone, thus

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decreases its bone resorptive effect.[3] It has been reported that increasing degree of mismatch between the implant body platform and the abutment can create more favorable marginal bone level conditions.[4] These findings are also encouraged by recent animal[5,6] and human histological studies.[7,8]

To evaluate the peri-implant soft and hard tissue conditions, numerous measures for early diagnosis are used before, during and after the placement of dental implants.[9,10] Peri-implant clinical indices, marginal bone levels, stability/mobility measurements by mobility measuring (MM) device and resonance frequency analysis (RFA) are non-invasive procedures that can be used for recurrent evaluations of dental implants.[10–12]

A valuable method to determine dental implant success is the assessment of crestal bone level changes in over time.[13,14] After the uncovering of a two-piece implant, remodeling take place at the bone margin and bone loss of ~1.5 to 2 mm both horizontally and vertically occurs during the first year of function with respect to microgap (the implant-abutment interface).[15–18] This type of bone loss occurs after the uncovering of submerged implants in a two-stage surgical procedure and the biologic width was reestablished.[16] The bone loss seems to be related to disclosing of the implant to the oral medium.[15–17]

To achieve successful osseointegration, primary implant stability has a vital role.[18] Primary stability is a local bone quality and quantity function and affected by the properties of an implant, and the preferred placement technique (whether a pre-tapped or self-tapped implant is used).[12] Mechanical characteristics of jaw bone is the main factor to achieve the successful osseointegration.[12,19–21] Marginal bone level changes around dental implants and stability measures at osteotomy sites are essential components of the evaluation of long-term success.[9,12,22]

While peri-implant sulcus fluid (PISF)-related measures is not a routine part of periodical assessments, this biologic fluid is considered to have a certain amount of diagnostic validity.[10,23] Analysis of different PISF ingredients (e.g., MPO, NO), fundamentally aims to better clarify the underlying molecular mechanisms in bone remodeling and inflammatory process around dental implant sites.[23]

Nitric oxide (NO) is a diatomic free radical produced by activated phagocytic leukocytes and it has both detrimental and beneficial effects on the pathophysiology of the tissues.[24,25] In the peri-implant region as well as the natural dentition, it has also been demonstrated that NO metabolism is closely related to the status and degree of peri-implant inflammation.[10] MPO is an antimicrobial leukocyte-derived enzyme found in high levels in the primary granules of leukocytes that catalyzes the formation of a number of reactive oxidant species.[26] The increased amount of MPO at sites with gingival inflammation and alveolar bone destruction in chronic and aggressive periodontitis suggests that MPO has a role in destructive periodontal disease.[27] MPO is also a good indicator of neutrophil activity in failed peri-implant sites compared with successful endosseous dental implant sites.[23,28]

The aim of this study was to compare the marginal bone loss, stability/mobility measurements and volume of myeloperoxidase (MPO) and NO of PISF between platform-switched (PS) and standard platform (SP) implants inserted in mandibular premolar/molar regions with a single-stage protocol.

MATERIALS AND METHODS

Patient Selection and Study Design

Patients suffered with partially edentualism referred to the Department of Periodontology at Hacettepe University were chosen. The study inclusion criteria were determined as: No patient was included under 18 years of age, tooth loss at mandibular premolar/molar region and residual bone volume had to allow placement of implants with diameter of 3.75 mm and with length of 11 mm. Six months to 1 year should exceed after tooth extraction. The patients had to be appropriate for the entire follow-up and maintenance schedule. The patients having systemic problems that would jeopardize the bone-healing process (osteoporosis, uncontrolled diabetes), severe parafunctional habits, drug or alcohol abuse, smoking, poor oral hygiene, untreated periodontal disease, and the need for tissue augmentation procedures during surgery were excluded from the study. The average age of the patients (10 women and 9 men) was 42.93 ± 10.33 years (age range 25–57 years). All patients were informed in detail about the study protocol and were asked to sign informed consent forms. The study was approved by the institutional review board of the university (Decision number: FON/08/33)

Two dental implant systems with tapered design used in the clinical study: PS system (Revois, Curasan,

Frankfurt, Germany) ($n = 16$) with 3.8 mm diameter and 11 mm length and the SP system (Tapered Screw Vent, Zimmer Dental, Carlsbad, CA, USA) with 3.75 mm diameter and 11.5 mm length ($n = 16$). All implants were inserted in mandibular premolar/molar region.

Surgical Procedures and Stability/Mobility Measurements

Patients received 1 g amoxicillin/clavulanate 1 hour before surgery and continued 2 g per day for 6 days.[29] All implant surgeries in the present study were performed by the same periodontist (ED). Patients were anesthetized by Ultracain D-S (Hoechst Marion Russel, Frankfurt/Main, Germany). A mid-crestal incision with sulcular releasing incisions at the adjacent teeth was performed. Full-thickness flaps were reflected and osteotomies were prepared at the mandibular premolar/molar sites as determined on dental computerized tomography before the surgical procedure. The implant surgeon classified the bone quality as demonstrated by Lekholm and Zarb during the drilling phase.[30] Prior to implant placement bone osteotomy sites were sterile saline irrigated. The insertion of implants to the bone cavities were performed by using a torque control system with 50 Ncm (W&H Dentalwerk Bürmoos GmbH, ImplantMED, Type: SI-923, Salzburg, Austria). Buccolingual width of the sites were measured prior to drilling sequence. Both implant system are produced according to two-stage surgical approach; however, they were used with single-stage surgical protocol in the present study. All implants were also placed according to the manufacturer's instructions and healing abutments were connected.

RFA device (Osstell, Integration Diagnostics AB, Göteborg, Sweden) was used to determine the implant stability. Smart pegs produced for each brand (Type 26, Ref No: 100425 for PS and Type 32 Ref No: 100440 for SP) were used to measure the stability of the implants. The RFA device measures the resonance frequency of a peg, which can be attached to the dental implant with the help of a cylindric plastic holder provided by the company. The probe of wireless RFA device was kept perpendicular to the jaw line as stated by the manufacturer for three buccal and three lingual measurements and mean implant stability value was calculated. The implant stability quotient (ISQ) value was appeared on the screen of the analyzer varying between +1 and +100. Wireless MM device (Periotest, Gulden-Medizintechnik, Bensheiman der Bergstraβe, Germany): This newer wireless electromechanical MM model specifically produced for dental implants is used to determine the mobility of the dental implant by generating a value ranging between −08 and +50. An electrically driven and electronically monitored tapping head percusses the healing cap or abutment of the dental implant buccolingually. Three measurements from buccal and three measurements from lingual side were carried out and mean value was calculated as the MM value of the implant. The values obtained are categorized by the manufacturer as follows: −08 to 0: good osseointegration, the implant is healthy integrated and pressure can be applied to it; +1 to +9: a clinical examination is necessary, the application of pressure on the implant is generally not possible; +10 to +50: osseointegration is insufficient and no pressure may be allowed to act on the implant.

Prosthetic Procedures

After 3 months of osseointegration, the definitive metal-ceramic crowns in occlusion were fabricated and cemented onto the abutments. In order to assess RFA and MM at each time point, all prosthetic crowns were cemented using temporary cement (Tempbond, Kerr, Salerno, Italy) in both PS and SP implants.

Radiographic Examinations

Periapical radiographs were obtained using a paralleling device (Dentsply Rinn, Rinn Cooperation, Elgin, IL, USA) at surgery and 1, 3, 6, and 12 months postoperatively. The radiographs were taken perpendicular to the long axle of the implant with parallelling technique, showing the whole implant and tissues on each side of the implant. Exposures were made using a KaVo Exam dental X-ray unit (Biberach an der Riss, Germany) operating at 70 kVp, 7 mA, and 0.115 seconds. Radiographs were digitalized at 2400 dpi using a flatbed scanner 10000 XL (Epson Expression 10000 XL, Seiko Epson Co., Nagano, Japan). Linear distance measurements were made based on the actual distance between two sequent threads of the implants provided by the manufacturers. The distance between first bone-implant contact and implant shoulder was measured. Image analysis software (ImageJ 1.43n, NIH, Bethesda, MD, USA) was used at ×400 magnification for the measurements. Mesial and distal bone measurements were

averaged for each implant to calculate proximal bone loss measures.

Follow-Up Procedures

RFA and MM measurements were done at the time of surgery (baseline) and 1, 3, 6, and 12 months follow-up. MM measurements were performed by tapping onto the top of the abutment, then the abutments were detached from the patients and smart pegs attached to the implants for RFA analysis. The following clinical parameters were recorded at 1, 3, 6, and 12 months to assess the clinical status of the dental implants including plaque index (PI),[31] gingival index (GI),[32] and probing depth (PD). All measurements were performed at four sites around each dental implant and were carried out to the nearest millimeter using a Michigan "O" probe (Hu-Friedy Manufacturing Company, Chicago, IL, USA). Wound healing index (WHI)[33] was recorded after surgery using the following criteria: score 1 = uneventful healing with no gingival edema, erythema, suppuration, patient discomfort, or flap dehisence; score 2 = uneventful healing with slight gingival edema, erythema, patient discomfort, or flap dehisence, but no suppuration; and score 3 = poor wound healing with significant gingival edema, erythema, patient discomfort, flap dehiscence, or any suppuration. All measurements were performed by the same periodontist (ED).

PISF Sampling

PISF samples were derived consistent with the method identified by Rüdin and colleagues[34] using standardized paper strips (Periopaper, no. 593525; Ora Flow, Amityville, NY, USA) at 1, 3, 6, and 12 months follow-up. In brief, after the isolation of the sampling area with sterile cotton rolls, supragingival plaque was removed by the help of a gauze, and the site was air-dried gently to reduce any contamination with plaque and saliva. Paper strips were located at the entrance of the peri-implant sulcus and were inserted to a standardized depth of 1 mm at each site irrespective of the PD. In order not to influence the actual fluid volume, sampling time was also standardized as 30 seconds. To eliminate the risk of evaporation, paper strips were immediately transported to a previously calibrated Periotron 8000 (Ora Flow, Amityville, NY, USA) located chairside for electronic volume determination. Before sampling, the Periotron 8000 was turned on and was allowed to warm up. A dry paper strip was placed in the device, and the reading dial was set to 0. To increase consistency, the calibration of the device was checked periodically by triplicate readings, as previously described.[35] The PISF volume was expressed electronically in Periotron units, which were converted to microliters (μL) by mlconvrt.exe software (Ora Flow, Amityville, NY, USA).[35] The PISF samples were then placed in sterile, wrapped Eppendorf tubes and stored at −20°C until the day of laboratory investigation. All PISF samplings were performed by the same periodontist (ED).

Determination of Nitrite Level in PISF

To each PISF/GCF sample in the Eppendorf tube, 300 μL extraction buffer (10 mmol/L phosphate buffer containing 0.5% hexadecyltrimethylammonium bromide, pH 6.0) was added, and the samples were vigorously mixed for the extraction of nitrite into the buffer. For the determination of nitrite levels, 150 μL of the extract was mixed with 150 μL of freshly prepared Griess reagent using a microplate. After 10 minutes of incubation at room temperature, the absorbance of each sample in microplate wells was determined at 540 nm.[36] A standard curve was prepared using sodium nitrite to calculate nitrite level in PISF.

Determination of MPO Level in PISF

The MPO level of the PISF/GCF was measured by spectrophometric MPO assay, a modification of the method reported by Suzuki and colleagues[37] Briefly, the assay mixture consisted of 50 mmol/L phosphate buffer (pH 5.4), 1.6 mmol/L synthetic substrate tetramethyl benzidine (TMB), 0.5% hexadecyltrimethyl ammonium bromide, 1 mmol/L H_2O_2, and 50 μL PISF extract. The reaction was initiated by the addition of H_2O_2, and the rate of TMB oxidation was followed at 655 nm using a recording spectrophotometer. The initial linear phase of the reaction was used to determine the change in absorbance per minute. One unit of MPO activity was expressed as the amount of enzyme producing one absorbance change under assay conditions. MPO activity in PISF samples was calculated and expressed as the total enzyme activity.

Statistical Analysis

SPSS 16.0 software for Windows (SPSS, Chicago, IL, USA) was used for all statistical analysis. For clinical parameters, stability/mobility parameters, PISF volume

and MPO and NO levels repeated evaluations were analyzed by variance analysis and student *t*-test was used to compare the groups when significant differences found between time points. Intragroup comparison was done by variance analysis. Friedman test was used for compare the data at all time points. *p* Values <.05 were considered statistically significant for all parameters.

RESULTS

All implants were inserted to quality 1 or 2 bone according to Lekholm and Zarb bone quality classification.[30] Each patient had received 1 or 2 implants with the same platform design. There were no statistically significant differences between groups with regard to age and gender distribution, bone quality, WHI, and buccolingual width of the crest at the time of surgery. The mean buccolingual width at baseline was measured as 7.06 mm for PS and 7.13 mm for SP implants ($p > .05$).

Radiographic Bone Loss Parameters

The changes in proximal bone loss at time points for both groups are summarized in Table 1. In PS implants mean bone loss was 0.10 ± 0.09 mm, 0.34 ± 0.24 mm, 0.72 ± 0.53 mm, and 0.84 ± 0.48 mm at 1, 3, 6, and 12 months, respectively. The corresponding values for SP group were 0.19 ± 0.24 mm, 0.31 ± 0.23 mm, 0.56 ± 0.35 mm, and 0.76 ± 0.42 respectively. Intragroup comparison between time points showed statistically significant differences between all time points ($p < .05$). However, there were no statistically significant differences between PS and SP implants at any point ($p > .05$).

Implant Stability/Mobility Parameters

ISQ Values. The mean ISQ values were 71.81 ± 5.34 and 76.4 ± 3.37 for PS and SP implants at surgery, respectively, and the corresponding values were 74.04 ± 4.25 and 76.00 ± 4.16 at 12-month recall (Table 2). There

TABLE 1 Mean Changes at Proximal Bone Levels at Follow-Up Period

	PS ($n = 16$)	SP ($n = 16$)	*p* Value
Bone loss (1 month)	0.11 ± 0.09	0.19 ± 0.24	0.69
Bone loss (3 months)	0.34 ± 0.24	0.31 ± 0.23	0.83
Bone loss (6 months)	0.72 ± 0.53	0.56 ± 0.35	0.48
Bone loss (12 months)	0.84 ± 0.36	0.76 ± 0.41	0.17

*$p < .05$ statistically significant compared to SP group.

TABLE 2 Mean ISQ and MM Values during the Study Period

	Baseline (Mean ± SD)		1 Month (Mean ± SD)		3 Months (Mean ± SD)		6 Months (Mean ± SD)		12 Months (Mean ± SD)	
	PS	SP	PS	SP	PS	SP	PS	SP	PS	SP
ISQ	71.81 ± 5.34*	76.4 ± 3.37	71.25 ± 7.44	75.87 ± 3.62	74.27 ± 3.88	76.4 ± 3.26	73.38 ± 5.27*	77.00 ± 2.75	74.04 ± 4.25	76.00 ± 4.16
MM	−4.26 ± 1.79*	−6.38 ± 0.98	−4.56 ± 1.59*	−5.87 ± 1.57	−4.74 ± 1.50*	−6.41 ± 1.30	4.75 ± 1.49*	−6.42 ± 1.30	−4.82 ± 1.52*	−6.26 ± 1.40

*$p < .05$ statistically significant compared to SP group.

TABLE 3 Comparative Statistics (*p* Values) of Implants within the Groups with Time

	PS			SP		
	ISQ	MM	Bone Level	ISQ	MM	Bone Level
Baseline versus 1 month	0.612	0.261	0.001*	0.418	0.714	0.008*
Baseline versus 3 months	0.421	0.382	<0.001*	0.721	0.623	<0.001*
Baseline versus 6 months	0.523	0.421	<0.001*	0.662	0.512	<0.001*
1 versus 3 months	0.432	0.523	0.001*	0.046*	0.651	0.008*
1 versus 6 months	0.462	0.631	0.001*	0.008*	0.626	0.008*
3 versus 6 months	0.632	0.67	0.001*	0.024*	0.328	0.008*
Baseline versus 12 months	0.520	0.316	<0.001*	0.524	0.511	<0.001*
6 versus 12 months	0.574	0.481	0.001*	0.621	0.664	0.006*

*$p < .05$ statistically significant difference within the groups between time points.

were statistically significant differences between groups at baseline and 6 months ($p < .05$). In PS implants, no statistically significant changes were found between all time points (Table 3). In SP implants, statistically significant differences were detected between time points including 1 and 3 months, 1 and 6 months, and 3 and 6 months ($p < .05$; Table 3).

MM Values. The mean mobility values were −4.26 ± 1.79 for PS and −6.38 ± 0.98 for SP implants at baseline and −4.82 ± 1.52 and −6.26 ± 1.4 at 6 months (Table 2). Statistically significant differences were found between groups at all time points. Intra group evaluation showed no statistically significant differences between time points in both groups (Table 3).

Peri-Implant Parameters

All peri-implant parameters at 1, 3, 6, and 12 months were overviewed at Table 4. No statistically significant differences were found between groups according to GI and PD values at any time points. According to intragroup comparisons no statistically significant differences were found in both implant types at all time points according the PI and GI values ($p > .05$; Table 5). According to PD values, no significant differences were found in PS implants between any time points. In SP implants, significant differences were found between 1 and 6 months ($p < .05$; Table 5).

PISF Parameters

Table 6 shows the overview of PISF parameters at 1, 3, 6, and 12 months There were no statistically significant differences between groups according to total nitrite level, MPO level and PISF volume at any time point ($p > .05$). According to PISF parameters, intragroup comparison showed no statistically significant differences between time points ($p > .05$)

DISCUSSION

The present study was intended to analyze the influence of PS concept on 12 months marginal bone level, PISF parameters, and stability/mobility measurement alterations where all implants were inserted with a non-submerged (single-stage) protocol. This study is a continuous of a previous study of our group where 6 months follow-up results were reported.[38] In addition to

TABLE 4 Peri-Implant Parameters during the Whole Study Period

	1 Month (Mean ± SD)		3 Months (Mean ± SD)		6 Months (Mean ± SD)		12 Months (Mean ± SD)	
	PS	SP	PS	SP	PS	SP	PS	SP
GI	0.67 ± 0.43	0.78 ± 0.29	0.83 ± 0.57	0.86 ± 0.38	0.81 ± 0.44	0.95 ± 0.34	0.86 ± 0.41	0.91 ± 0.39
PI	0.38 ± 0.17	0.53 ± 0.35	0.43 ± 0.30	0.61 ± 0.28	0.45 ± 0.27	0.56 ± 0.31	0.42 ± 0.28	0.50 ± 0.32
PD	2.00 ± 0.33	1.77 ± 0.40	1.99 ± 0.34	2.07 ± 0.35	2.23 ± 0.46	2.15 ± 0.36	2.21 ± 0.44	2.17 ± 0.71

*$p < .05$ statistically significant compared to SP group.

TABLE 5 Comparative Statistics (*p* Values) of Peri-Implant Parameters within the Groups with Time

	PS			SP		
	GI	PI	PD	GI	PI	PD
1 versus 3 months	0.258	0.342	0.204	0.258	0.651	0.102
1 versus 6 months	0.462	0.421	0.030*	0.023*	0.626	0.040*
3 versus 6 months	0.632	0.521	0.124	0.102	0.328	0.261
1 versus 12 months	0.312	0.262	0.020*	0.03*	0.512	0.022*
6 versus 12 months	0.412	0.326	0.226	0.106	0.422	0.314

*$p < .05$ statistically significant difference within the groups between time points.

the bone level, stability-mobility, and clinical measurements of the previous study, we performed PISF volume and NO-MPO analysis for further clarification of the influence of PS on the biological mechanisms around dental implants. Molecular changes around dental implants are complex and a close relationship has been demonstrated between inflammatory conditions and molecular patophysiology.[23,28] This may be the reason for increasing interest on PISF analysis to explore the potential molecular and enzymatic changes as a result of inflammation.[10,23,28] MPO is an enzyme located at the azurophilic granules of polymorphonuclear leukocytes, and it contributes to protease activity and connective tissue breakdown through changing the protease/antiprotease balance.[27,28] Different studies demonstrated the role of MPO on peri-implant disease progression, and it can be concluded that MPO could be a promising marker of inflammation around dental implants.[10,23,28] NO has been considered an important signaling molecule in various tissues with beneficial and harmful effects.[24,25] In the peri-implant region like the natural dentition, it has been demonstrated that NO metabolism is closely related to the status and degree of peri-implant gingival inflammation.[10] Inducible NO synthase is expressed as a response to inflammatory stimuli and causes higher amounts of NO production.[25] It has been reported that due to macrophage infiltration into the periodontal tissues, NO synthesis is increased in periodontal disease.[39] End products of NO and MPO are considered to reflect the degree of oxidative stress.[40] Because of the difficulty to direct measurement of NO from body fluids due to its high reactivity and short half life, in this study, nitrite level was analyzed which is a stable end product of NO and serve as a general measure of NO metabolism.[41] The nonsignificant differences between groups according to MPO, nitrite levels, and PISF volume can be interpreted as a sign of uneventful healing of all implants. Platform-switching concept seems not to affect the PISF volume and NO and MPO metabolism in this study.

Biologic feature, for instance, biological width establishment, has been suggested to be associated with crestal bone resorption.[42] PS concept necessitates the implant-abutment interface to be positioned away from the implant shoulder and closer toward the axis in order to increase the distance between microgap and the bone.[1,2,43] In this study, the implant system used as PS has a microrough and nanorough surface extending to the implant shoulder, accommodating biologic width by featuring a prepared margin 1.9 mm above the shoulder. Consistent with PS concept, it has a standard abutment diameter of 3.05 mm. The system used as SP has butt joint connection with matching abutments and 1.0 mm polished surface at the implant shoulder. In the present study, at the end of the 12-month period, the mean marginal bone loss was 0.84 and 0.76 mm for PS and SP implants, respectively. No statistically significant differences were found between implant types. The degree of the marginal bone level alterations observed wide-ranging among the studies.[2,44] The different results of the studies possibly due to different observation periods, implant designs, study populations, and radiographic analysis techniques. However, compared with control implants with matching abutment-implant dimensions, these studies could demonstrate statistically significant less marginal bone loss as assessed on radiographs at implants restored according to the PS concept.[3] According to periodontal structural biology, concerning the formation of a long junctional epithelium after root planning, in which apical proliferation is restricted by connective tissue fibers inserting on the tooth surface can also be applied to the peri-implant situation.[44]

TABLE 6 PISF Parameters during the Whole Study Period

	1 Month (Mean ± SD)		3 Months (Mean ± SD)		6 Months (Mean ± SD)		12 Months (Mean ± SD)	
	PS	SP	PS	SP	PS	SP	PS	SP
MPO (U)	0.474 ± 0.114	0.521 ± 0.182	0.543 ± 0.214	0.526 ± 0.118	0.586 ± 0.163	0.513 ± 0.241	0.618 ± 0.162	0.546 ± 0.175
Total nitrite (nmol)	0.184 ± 0.053	0.190 ± 0.046	0.189 ± 0.042	0.191 ± 0.041	0.186 ± 0.034	0.188 ± 0.043	0.185 ± 0.049	0.187 ± 0.039
PISF volume(µL)	0.438 ± 0.116	0.471 ± 0.129	0.397 ± 0.213	0.407 ± 0.174	0.452 ± 0.182	0.446 ± 0.161	0.492 ± 0.224	0.498 ± 0.199

Apical proliferation of epithelium and associated bone loss might be prevented by a well-organized connective tissue attachment to the titanium surface. In the present study, all implants placed at the bone crest and healing abutments used for single-stage procedure. In agreement with Hermann and colleagues, this procedure may be harmful to the connective tissue attachment process and facilitate the apical migration of the epithelial tissue to the bone and limits the protective effect of platform switching.[44]

One of the key factors for the success of implants is dental implant-bone contact, and there are numerous ways to evaluate the implant-bone interface as RF analysis and MM devices.[20,21,45–47] In the present study, the RFA scores (72–77 ISQ) and MM values (−3 to −7) indicated an acceptable level of implant stability/mobility. The mean MM values were significantly lower for SP implants compared with PS implants at all time points. The lack of significance in the difference of MM values in intragroup comparison may be attributed to a smaller range of measured values compared with other methods and also different application points during MM measurements.[48] This finding is in agreement with other studies that describe the limitations of MM device in the measurement of implant mobility.[49,50] In the present study, the SP implants may be presumed to have better implant stability/mobility than the PS implants. According to ISQ values, SP implants showed a decrease until 3 months, which was followed by an increase, and PS implants did not show any difference between time points. Some studies have suggested that primary stability is related closely to implant design, particularly, to the design and geometry of the thread.[51,52] No significant differences were found between groups according to bone quality thus, the difference of primary stability values between the two implant types may be explained by the differences in the implant and thread design.

However, our findings should be interpreted with caution because the study presents certain limitations such as a small sample size and a lack of data regarding the impact of the platform-switching concept on microbiological parameters[53,54] and the esthetic treatment outcome.[55] Canullo and colleagues reported that the marginal bone level alterations associated with platform switching are not influenced by the submucosal implant microbiota.[54] Pieri and colleagues demonstrated no significant differences between two implant-abutment interfaces according to soft tissue level and papilla

height.[55] Another limitation of this study that apart from the platform-switching concept the PS and SP implants used in this study were also differed in other aspects from each other. It could be a confounding factor; however, standard implant dimensions and same protocol used to minimize this effect and this limitation can be applied to certain studies of this kind.[56,57]

The findings of the present clinical study regarding various implant site-related and specific measures suggested that not all measures of the same dental implant site were related or dependent. As several complex mechanisms and relations seem to have effect at dental implant sites, each parameter, including clinical, image-based measures, is expected to be associated with a particular aspect of these mechanisms.[58] The long-term evaluation of the possible differences among various implant-related measures, and among different implant platform and abutment designs may increase our understanding in this field.

CONCLUSIONS

Within the limits of this study, platform switching seems not to affect the marginal bone level, clinical peri-implant parameters and MPO and NO metabolism around implants placed in mandibular premolar/molar regions using a single-stage protocol. Non significant differences between laboratory based analyses could be attributed to uneventful healing of all implants and healthy peri-implant inflammatory conditions. Further studies are necessary to explore the effects of PS on laboratory, diagnostic and image-based measures.

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